Are historical stage records useful to decrease the uncertainty of flood frequency analysis? A 200-year long case study

Flood frequency analysis (FFA), a widely used method to estimate flood hazard, is affected by several sources of uncertainty. Extending flood samples by reanalyzing historical continuous stage records has the potential to reduce sampling uncertainty, but the historical flood discharges derived from this reanalysis are generally affected by large uncertainties. This paper explores whether historical stage records improve design flood estimates through a chain of uncertainty estimation methods for FFA. Uncertainties are estimated and propagated from stage and rating curves to design flood estimates using Monte Carlo procedures. The role of both streamflow and sampling uncertainties in design flood estimation is examined. This procedure is applied to the 205-year long continuous stage series of the Rhône River at Beaucaire, France (95 590 km²). The estimated streamflow 95% uncertainty varies from 30% (XIXth Century) to 5% (1967-2020). The total uncertainty of design flood is significantly reduced when the length of the series increases from 20 to 100 years due to sampling uncertainty reduction. However, the total uncertainty remains stable beyond this sample size: this is because large uncertainties affecting the XIXth Century flood discharges compensate for the reduction in sampling uncertainty. Enlarging the sample size to two centuries leads to including the two largest known floods in 1840 and 1856. In turn, this induces a 15% increase of the 1000-year flood estimates.

**Keywords**: Flood frequency analysis, Historical stage records, Uncertainty propagation, Streamflow uncertainty, Sampling uncertainty